CULTURES OF HETEROECIOUS RUSTS

W. P. Fraser

The cultures described in the following pages were undertaken during the spring and early summer of 1911. Special attention was given to the study of the aecia on conifers and their connection with telial forms, but a few cultures of the grass and sedge rusts that field observation suggested were also tried. The success attained was largely due to the excellent opportunity for field observation that the region afforded and the ease with which material could be collected.

The teliosporic material used in the cultures was collected in the districts surrounding the town of Pictou. The greater part was obtained in the spring, but considerable material was collected the previous fall and was left exposed to the weather during the winter in small cheese cloth bags. When the host plants were ready for infection, the leaves or parts of the plants bearing telia were placed in a moist chamber on damp blotting paper and then sprayed with water by means of an atomizer. When it was found by examination that the teliospores had germinated, the germinating teliosporic material was suspended above the host plants so that the basidiospores would fall on the leaves, the whole was then sprayed by an atomizer and covered for from one to several days with a bell jar. This method was satisfactory except that it frequently gave such rich infection that the plants were killed by the abundant pycnia. In all cases the teliospores were found to be germinating before the sowing was made unless stated otherwise in the descriptions. Sometimes it was found that the teliospores did not germinate in the moist chamber for several days; in some cases five to seven days were required for germination, in others a day or less was sufficient. The teliospores of the *Melampsoropsis* rusts, which mature and germinate on the living host plants in the spring, were collected when germinating, or the mature telia were placed immediately after collection in a moist chamber until they germinated freely, which usually took place in about twenty-four hours.

Many of the host plants used in the cultures were obtained in the field and placed in pots in early spring, but some were procured a short time before the experiments were made. Care was taken to select the plants remote from any source of infection and the surrounding plants of the same species from where they were obtained were kept under observation and remained free from infection except in one case which is noted in the description of the experiment. Plants from the same place as those used for the cultures were also kept as checks in every experiment and in no case did infection appear.

The experiments were carried on in a well-lighted laboratory of Pictou Academy, with the exception of one at the end of the season which was performed at the Agricultural College, Truro, N. S.

The writer's thanks are due to Dr. J. C. Arthur for valuable suggestions and assistance, to Professor H. W. Smith, Biologist of the Agricultural College, Truro, for enthusiastic and valuable assistance in field observation in the vicinity of Truro and in the culture carried on at the College, and also to Mr. John Macoun, Naturalist of the Geological Survey of Canada, for determining some of the host plants.

PUCCINIASTRUM PUSTULATUM (Pers.) Dietel

During the summer of 1910 there was a very luxuriant development of this rust on *Epilobium angustifolium* L. in a small area that had been previously swept by fire. The leaves with telia were collected the following spring and gave excellent germination after from four to six days in a moist chamber. A sowing was made on *Abies balsamea* on May 17. Pycnia were noticed on May 24 and aecia on June 1. Another sowing on May 22 gave pycnia on May 29 with aecia on June 4. Infection was very marked in both cultures, practically all the young leaves being infected. Another sowing was made on June 19 with a few pycnia on June 27 and aecia on July 4. By this time the leaves of the host plants were becoming mature and the infection was sparing. A sowing was also tried on *Tsuga canadensis* but without result.

Aeciospores from the culture aecia were sown on *Epilobium*

angustifolium L. on June 14 and the uredinia of *Pucciniastrum pustulatum* were noticed about two weeks later.

In the field where the telia for the culture were collected, a few trees of *Abies balsamea* grew among the rusted *Epilobium.* These were watched for the appearance of pycnia and aecia and the first collection was made on June 19, when the pycnia were well developed but the aecia were not mature. Several collections were made later but the aecia were few considering the abundance of the telia and the fact that all tested in the laboratory gave excellent germination. Probably the scant development was due to the very dry weather that prevailed during May and June until the leaves of the host were too old to be readily infected. In the laboratory tests, at least four days in a moist chamber were necessary for the germination of the teliospores.

European investigators have shown that the aecial stage of this rust is on *Abies pectinata* DC., but as far as the writer is aware these are the first experiments with American material and the first collection of aecia in North America.

CALYPTOSPORA COLUMNARIS (A. & S.) Kuhn

The swollen stems of *Vaccinium pennsylvanicum* Lam. bearing the telial stage of this rust were placed in a moist chamber on May 12 and the teliospores were germinating freely by May 17. A young plant of *Abies balsamea* (L.) Mill. was then infected on the latter date in the usual way. Aecia were first noticed appearing on June 3 and were mature by June 12. There was no trace of pycnia. An attempt was made to infect *Tsuga canadensis* (L.) Carr., but without success.

In the field, aecia began to appear during the last week of June and were abundant on the host in this region (*Abies balsamea*) during the first and second weeks of July.

Arthur (Mycol. **2**: 231. 1910) infected *Abies Fraseri* (Pursh) Poir, using telial material from this region. This is the only previous culture with North American material.

MELAMPSOROPSIS LEDICOLA (Peck) Arthur

Teliosporic material of this rust on *Ledum groenlandicum* Oeder was *sown on Picea canadensis* (Mill.) BSP. on June 5.

Pycnia were evident on June 13 in great abundance and aecia followed in two or three weeks. Two host plants were used and the infection was marked on both. The aecia were without doubt *Peridermium decolorans* Peck. Another sowing on June 17 gave pycnia on June 27 followed by aecia. This confirms the work of last year. (Mycol. 3: 70. 1911.)

MELAMPSOROPSIS CASSANDRAE (Peck & Clinton) Arthur

Teliosporic material of this rust on *Chamaedaphne calyculata* (L.) Moench was sown on *Picea rubra* (DuRoi) Dietr. on June 16; pycnia were noticed on June 26, and aecia were mature by July 16. Both pycnia and aecia were very abundant. Another sowing on *Picea mariana* (Mill.) BSP. on June 17 gave pycnia which were noticed first on July 3. Aecia followed, but not in abundance, probably owing to the maturity of the leaves. The aecia belonged to *Peridermium consimile* Arthur and Kern. Frequent collections of aecia were made in the field on the *Picea* that grew beside the *Ledum,* which bore germinating telia in the spring. (For previous culture see Mycol. 3: 68. 1911.)

MELAMPSOROPSIS ABIETINA (A. & S.) Arthur

Teliosporic material on *Ledum groenlandicum* was sown on *Picea rubra* on July 16, with pycnia on June 27 and aecia on July 8, both in great abundance. A sowing was tried on *Picea canadensis* without result, but the leaves were too old for the experiment to have any value as negative evidence. This confirms the work of last year (Mycol. 3: 69. 1911). The aecia were found to be *Peridermium abietinum.* Several collections were made in the field beside where the telia were germinating on *Ledum* in the spring.

UROMYCES SCIRPI Burr.

Teliosporic material of this rust on *Scirpus campestris* var. *paludosus* (A. Nelson) Fernald (*S. paludosus* A. Nelson) was sown on *Cicuta maculata* L. on June 9. Pycnia appeared on June 16 and aecia followed in a short time, both in abundance. Arthur (*Jour. Myc.* 13: 199. 1907; 14: 17. 1908; Mycol. 1:

237. 1909) has shown by cultures that this rust on *Scirpus fluviatilis* (Torr.) A. Gray has aecia on *Cicuta maculata.*

A species of *Uromyces* on *Scirpus validus* Vahl. was collected near Pictou. The collection differed from typical *Uromyces Scirpi* in having the telia embedded in the tissues and placed immediately beneath the stomata. The teliospores are also short pedicelled and mostly irregular in shape. Dr. Arthur places this collection under *Uromyces Scirpi.* Attempts were made to germinate the teliospores but without success.

UROMYCES PECKIANUS Farl.

Teliosporic material of this rust on *Distichlis spicata* (L.) Greene collected near Pictou was sown on *Atriplex patula* L. on May 16 with pycnia on May 25 and aecia appearing by May 30. Another sowing was made on June 3 with pycnia on June 10 followed by aecia which were mature by June 24. A sowing on *Chenopodium album* L. on June 2 showed pycnia by June 10 followed by abundant aecia which were mature by June 23. These experiments confirm the work of last year (Mycol. 3: 72. 1911).

Two successful sowings were also made on *Salicornia europaea* L., but with such scant infection that little value can be placed on the experiments. It is very probable, however, that the aecia on *Salicornia* belong to this species. The morphology of the aecia support this view.

Attempts were also made to infect *Suedia maritima* (L.) Dumort and *Spergularia canadensis* (Pers.) Don., but without success. It seems probable to the writer, however, that the aecia collected on *Suedia* among the rusted *Distichlis* is connected.

PUCCINIA PERPLEXANS Plow.

Teliosporic material of this rust on *Alopecurus pratensis* L. was collected near Pictou and sowings were made on two plants of *Ranunculus acris* L. June 2. Pycnia were noticed on both June 11 and aecia began to appear June 21. The infection was marked on both plants, the leaves, stem and pedicels being infected.

Aecia developed abundantly in the field on *Ranunculus acris* L.

that grew among the rusted *Alopecurus*. The first collection was on June 28.

The life history of this species has been worked out by Plowright and other European investigators, but this is the first experiment with North American material, so far as the writer is aware.

PUCCINIA ALBIPERIDIA Arth.

A few collections of *Puccinia* on *Carex* were sown successfully on *Ribes* as described below. All are placed under this species for the present, until further study determines their true position.

Puccinia on *Carex intumescens* Rudge was sown on *Ribes prostratum* L'Hér on May 3 with abundant pycnia and aecia on May 12 and May 24 respectively. Another sowing on the same host on May 25 showed pycnia on May 30 followed by aecia in a short time. Two attempts were made to infect young thrifty plants of *Ribes oxyacanthoides* L. but without success. A sowing on *Sambucus racemosa* L. also failed.

Puccinia on *Carex crinita* Lam. was sown on *Ribes oxyacanthoides* L. on May 7 followed by pycnia on May 15 and aecia on the 24th, both in abundance. Another sowing on the same host on June 16 was followed by pycnia on June 21 and aecia on July 2. Infection was very abundant on the young stems and leaves. A sowing on *Ribes prostratum* on May 6 showed pycnia on May 14 and aecia on May 24. Arthur (Jour. Myc. **14**: 13. 1908) sowed teliosporic material from *Carex crinita* successfully on *Ribes Cynosbati* L.

Puccinia on *Carex debilis* var. *Rudgei* (*Carex tenuis* Rudge) was sown on *Ribes prostratum* on May 21 with pycnia on May 29, followed in a short time by many aecia. A collection from this region was sown on *Ribes Cynosbati* the preceding year by Arthur (Mycol. **4**: 13. 1912).

Puccinia on *Carex arctata* Boot. was sown on *Ribes oxyacanthoides* on June 2. Pycnia appeared abundantly on June 11. Aecia appeared but they did not flourish and only a few matured. Sowings were also tried on *Sambucus racemosa* and *Aster acuminatus* Michx. but without infection.

PUCCINIA CARICIS-SOLIDAGINIS Arth.

A collection on *Carex scoparia* Schk. was sown on *Solidago graminifolia* (L.) Salisb. on May 7 with pycnia May 25 and aecia on June 13. Arthur (Mycol. 4: 15. 1912) established this connection with teliosporic material collected in Maine.

A *Puccinia* on *Carex stipata* Muhl. heretofore called *Puccinia Peckii,* was sown on *Solidago* (*rugosa?*) on June 5 with very abundant pycnia on June 11, but the plants died soon after, so that the aecia did not mature. Strong field evidence of connection suggested the sowing. It seems from the culture and the field observations that the *Puccinia* on *Carex stipata* which has passed as *Puccinia Peckii* in this region belongs to *P. Caricis-Solidaginis.*

PUCCINIA ASTERIS-CARICIS Arth.

Teliosporic material from *Carex trisperma* L. was sown on *Aster acuminatus* Michx. on June 12 with pycnia on June 20 and aecia by July 1, both in great abundance. Another sowing on July 10 on the same host also gave abundant pycnia and aecia. This connection was supported by strong field evidence.

UROMYCES PERIGYNIUS Halst.

A collection of teliosporic material on *Carex deflexa* Hornem. was sown on *Solidago* (*rugosa?*) on May 25 with pycnia on June 1 and aecia on June 21. Another sowing on May 25 on *Solidago bicolor* L. gave pycnia on June 6 followed by aecia on June 21, both in abundance.

Another collection on *Carex scoparia* was sown on *Solidago graminifolia* (L.) Salisb. on May 28 with very abundant pycnial infection by June 6. The plants died in a few days, probably from the severe infection. The field evidence of the connection of these forms was as conclusive as such evidence could be.

A collection on *Carex intumescens* was sown on *Solidago* (species undetermined) successfully. Field evidence of connection suggested a sowing on *Aster* which was made on June 15, with very abundant pycnia on June 25 but the plants died in a few days later, probably from the severe infection, so that no aecia developed. The species of *Aster* was probably *puniceus,* but a certain determination could not be made.

These experiments tend to confirm the experiments of Arthur (Mycol. 4: 21. 1912) with this species and add another telial host, *Carex scoparia,* as anticipated.

NECIUM FARLOWII Arth.

This rust was found to occur abundantly during the summer of 1910 on the leaves and twigs of a number of trees of *Tsuga canadensis* that grew near Pictou. It was most common on trees from ten to fifteen feet in height and practically all the twigs at the top of the infected trees were killed by the fungus. The rusted leaves soon fell away but the twigs remained during the winter. Some of these twigs bearing telia were collected in the fall and wintered. Collections were also made from the trees in the spring, and both collections gave good germination in a moist chamber in a few days.

A sowing was made on *Tsuga canadensis* on June 5 and by the 14th the leaves began to turn yellow, indicating infection and telia were present by the 21st. No pycnia were formed. Another trial on June 11 gave telia by June 27 and a third on June 14 was also successful, the telia being first noticed on June 27. Telia began to form on the twigs a few days later than on the leaves.

The infected twigs that remained on the trees in the field were observed germinating on June 14 after a day or two of showery weather. The germinating telia could be easily recognized on close examination as they became reddish in color and swollen and velvety in appearance. Microscopic examination showed the promycelia to be rather large with spherical basidiospores 8–10 μ in diameter, of a deep reddish color. The young leaves in the vicinity of the germinating telia began to show infection by the first of July and well developed telia were collected on July 5. Infection of the twigs soon followed. The cones on the overhanging branches of a large hemlock also became infected, the first collection being made on July 8.

Arthur in NORTH AMERICAN FLORA regards this species as possessing telia only and possibly pycnia. These observations and experiments confirm this view and indicate that pycnia are absent.

MELAMPSOROPSIS PYROLAE (DC.) Arthur

The association of this rust with *Peridermium conorum-Piceae* (Rees) Arthur was discussed in a previous paper (Mycol. 3: 70. 1911). This season's experiments were carried on for the purpose of establishing the connection of these forms.

Three trees of *Picea mariana* (Mill.) BSP. were taken into the laboratory just when the cones were bursting the scales, and on May 26 plants of *Pyrola* bearing germinating teliospores were suspended above so that the basidiospores would fall on the cones. Two of the trees soon died, the third grew for a time and the cones developed. Pycnia were noticed on June 17, followed by the aecia of *Peridermium conorum-Piceae*. The aecial spores were being shed by July 16. Only one cone became infected, out of about fifteen that grew on the tree.

Experiments were also tried in the field. Two trees about fifty yards apart were selected in a grove of *Picea* on a point that juts into the harbor. The grove was surrounded on the landward side by cultivated fields and was a mile or more distant from any suspected source of infection. Plants of *Pyrola* bearing germinating teliospores were suspended on May 29 above the cones as in the experiment in the laboratory, provision being made to keep their roots moist. On June 26 the cones of both trees were covered with pycnia which probably appeared a week or more earlier, as only occasional visits were made to the place. Aecia were present by July 4 and the spores were being shed by July 8. One of the trees was *Picea mariana;* of the 21 cones that it bore, all but one were infected. There were 14 cones on the other tree (*Picea canadensis*), of which 9 were infected. The cones of the trees (*Picea*) that grew everywhere near were carefully examined and no infection was found in the vicinity or within more than a mile of the place where the experiments had been made. When the aecial spores are being shed the infected cones are conspicuous and not likely to be overlooked especially on small trees. Even the pycnial stage is also conspicuous as the scales turn yellow, and yellow-colored resin oozes freely from the cones. The most of the trees in the grove were small, not over 20 feet in height, but cones were plentiful. For convenience, the smallest trees with few cones were selected for the experiments.

The plants of rusted *Pyrola* used in the experiments were *Pyrola americana* Sweet and *P. elliptica* Nutt.

While the experiment in the laboratory cannot be regarded as conclusive owing to the scant infection and the remote possibility of the cones having been infected before the trees were taken in to the laboratory, yet the experiments in the field seem to the writer to show beyond reasonable doubt that *Peridermium conorum-Piceae* is the aecial stage of *Melampsoropsis Pyrolae.*

The poor infection in the laboratory experiments may have been due to the fact that the tree was not in a flourishing condition or that the provision made to keep the atmosphere moist about the cones was not sufficient, or, as the writer believes, to the cones not being old enough when the sowing was made. In the field experiments the cones were more mature. It was also found that *Pucciniastrum minimum* readily infected the cones of *Tsuga* when they were so far developed that infection was regarded as doubtful.

In the region where the *Pyrola* rust was collected, the teliospores began to germinate about May 24. The pycnia of *Per. conorum-Piceae* were noticed on the cones of *Picea mariana* in the vicinity on July 1, and the aecial spores were being shed on July 16. The *Peridermium* was rather rare, only a cone or two showing infection on the trees attacked, and in all only about two dozen cones were collected, where they could be collected in hundreds the preceding season.

PUCCINIASTRUM MINIMUM (Schw.) Arthur

During the summer of 1910, in a small area that had previously been swept by a fire, a very luxuriant growth of *Rhodora canadense* (L.) BSP. resulted, and on the leaves of the *Rhodora* a splendid development of the uredinia and telia of this rust was present. To gain some clue to the aecial stage, leaves were gathered in early spring and placed beneath small trees of *Abies canadensis* and *Tsuga canadensis* and small trees of the same species were planted among the rusted *Rhodora.* Trees of *Picea* grew near the *Rhodora,* so these were not experimented with. It was thought most probable that the aecial host was either *Abies* or *Tsuga.*

Leaves with telia were also collected and the teliospores were

germinated in a few days in a moist chamber. A sowing was made on *Abies balsamea* and *Tsuga canadensis* on June 13 with pycnia on the latter on June 20, and aecia on July 1, but without infection on the former. Another sowing on the same hosts on June 17 gave pycnia on *Tsuga canadensis* on June 26 and aecia on July 4 but without infection on *Abies*. A third sowing was made with the same results.

In the field the infected leaves of *Rhodora* had been placed under two trees of *Tsuga canadensis* in different places and in both there was a most decided infection of the neighboring leaves; the trees of *Tsuga* that had been planted among the rusted *Rhodora* also developed aecia, but *Abies* did not. The writer's attention was now called to Arthur's description of *Per. fructigenum* (Bull. Torrey Club **37**: 578. 1910) on the cones of *Tsuga ciniastrum minimum*, and also to Spaulding's collection of aecia on the leaves of the hemlock which he regarded as belonging to this species (Phytopath. 1: 94. 1911). Experiments were now tried to determine if the cones could be infected.

As it was not practicable to take cone-bearing trees of *Tsuga canadensis* into the laboratory, branches with cones were placed in water and a fresh surface was exposed to the water every day or two by removing a small portion of the end of the twig. A sowing was made on the cones and leaves on June 18 with abundant pycnia on the cones and leaves on June 26. Aecia developed abundantly on the leaves by July 8 and a few aecia appeared on the cones a day or two later. Another sowing was made on June 22 with pycnia on the cones and leaves in abundance on July 2 and aecia on the leaves by July 8, also in abundance. Two or three days later a few aecia appeared on the cones.

About the same date, during a day or two of showery weather, leaves of the *Rhodora* with germinating telia were collected in the field and placed on the cones of a large tree of *Tsuga canadensis*. Some of the material was also thrown beneath and over a small tree of the same species. Pycnia appeared abundantly in about a week on the cones and leaves of both trees. There was also a most luxuriant development of aecia on the leaves, but only a few aecia matured on the cones.

Dr. Spaulding generously furnished material from his collec-

tions of *Peridermium fructigenum* Arth. for comparison, but it seemed to be distinct from the culture aecia. Several collections of aecia were made during the summer of 1910 and 1911 in various parts of the province on *Tsuga canadensis*. These collections were regarded by the writer as *Peridium Peckii* and the field evidence clearly indicated a connection with *Pucciniastrum Myrtilli* on *Vaccinium pennsylvanicum* and *V. canadense*. The culture aecia, both field and indoor, of *Pucciniastrum minimum* were so much paler in color than the aecia regarded as *Peridermium Peckii* that the writer was inclined to consider them distinct. Material was sent to Dr. Arthur for determination. He replied that the aecial form from *Pucciniastrum minimum* was *Peridermium Peckii* and the form that seemed to be connected with *Pucciniastrum Myrtilli* was distinct.

These cultures seem to the writer to prove that the aecia of *Pucciniastrum minimum* (Schw.) Arthur are on the leaves and cones of *Tsuga canadensis* and according to the determination of Dr. Arthur belong to *Peridermium Peckii* Thüm.

UROMYCES SPARTINAE Farl.

For three successive years aecia were collected on *Spergularia canadensis* (Pers.) Don near Pictou. The aecia seemed to be connected with *Uromyces Spartinae* on *Spartina patens* (Ait.) Muhl. and *S. glabra* var. *alterniflora*. Attempts were made, in the spring of 1910, to test this supposed connection by cultures, but the teliospores failed to germinate. On June 10, 1911, aecia were found to occur very abundantly on *Arenaria lateriflora* L. in several places, and in each the distribution of the aecia seemed to leave no doubt that they were connected with the *Uromyces* on *Spartina Michauxiana* Hitch. As abundant material of this rust on the three species of *Spartina* common in this region had been collected in early spring for use in culture work and was found to give good germination, experiments were tried to test the suspected connection.

A sowing of teliosporic material from *Spartina Michauxiana* was made on *Arenaria lateriflora* on June 11 with pycnia on June 17 and aecia on June 27, both in abundance on the young leaves and stem. Another sowing on June 12 gave pycnia on June 18

and aecia on June 27, also in abundance. Another sowing on June 27 gave pycnia on July 7 and aecia on July 16, but not in such abundance, probably owing to the maturity of the leaves. Three different sowings were made on *Spergularia canadensis* and one each on *Stellaria media* (L.) Cyrill., *S. graminea* L., and *Glaux maritima* L. without infection in any case.

Teliosporic material from *Spartina glabra* var. *alterniflora* was sown on *Spergularia canadensis* on June 12 with pycnia on June 20 and aecia on June 27. A previous sowing on the same host was successful, but the dates were not kept. Two sowings were made on *Arenaria lateriflora* without infection.

A sowing of teliosporic material from *Spartina patens* was made on *Spergularia canadensis* on June 12 with pycnia on June 20 and aecia on June 27. Two further sowings made, one on June 27 and the other on the 28th, were also successful, producing pycnia and aecia in due time. Two sowings were made on *Arenaria lateriflora* and one on *Salicornia europea* without infection.

The field observations and cultures show that *Uromyces Spartinae* on *Spartina Michauxiana* has aecia on *Arenaria lateriflora* but not on *Spergularia canadensis,* while the same rust on *S. patens and S. glabra* var. *alterniflora* has aecia on *Spergularia canadensis* and not on *Arenaria lateriflora.*

Dr. Arthur studied the field collections and culture material here described for vol. 7, part 3, of NORTH AMERICAN FLORA, which includes this species. His conclusions in regard to the position of this species can be gathered from his treatment of it in that work.

MELAMPSORA ARCTICA Rostr.

A species of *Caeoma* was found to occur abundantly on *Abies balsamea* during the early summer of 1910. A collection of the material was sent to Dr. Arthur, who suggested that it might be the aecial stage of *Melampsora arctica* Rostr. Field study confirmed this suggestion, as the willows in the neighborhood of the *Caeoma* soon developed uredinia and telia of *Melampsora artica* Rostr. Leaves with telia were collected in the fall and wintered and the teliospores gave good germination in a few days in a moist chamber. A sowing was made on *Abies balsamea* on May

27. Pycnia appeared on June 2 followed by aecia in a few days. Another sowing was made on two trees of the same host on May 30, with pycnia by June 3 and aecia by June 10. Two different sowings were made on *Larix laricina* (DuRoi) Koch but no infection followed. The willow from which the teliosporic material used in the experiments was obtained was determined as *Salix discolor* Muhl. by John Macoun. Collections were also made on *Salix rostrata* Richards.

The *Caeoma* was not so common in the summer of 1911 as in the previous season, probably owing to the dry weather, but the collections made were in the vicinity of willows that were infected with this rust the preceding year. It does not seem to have been previously collected. The pycnia are numerous, hypophyllous; the aecia hypophyllous, rather large and conspicuous; the aeciospores ovoid or globose, 13–16 × 15–24 μ; wall rather thick, 2–3 μ, finely verrucose; contents orange.

MELAMPSORA (MEDUSAE Thüm.?)

During the summer of 1910 several small hemlocks in the natural park at Truro, N. S., were observed to be so severely infected by *Caeoma Abietis-canadensis* Farl. that it suggested local infection. In the fall of the same year, the writer, in company with Professor H. W. Smith, of the Truro Agricultural College, visited the place and careful search was made for some clue to the telial stage. No rust was found in the vicinity, except a *Melampsora* on *Populus grandidentata* Michx., several trees of which grew near. This was regarded as *Melampsora Medusae* Thüm. and examination seemed to confirm this view. As the aecial stage of this rust has been shown to occur on *Larix,* the proximity of the poplar rust was thought to be of little significance.

Teliosporic material on *Populus grandidentata,* however, was collected near Pictou in the spring, and on June 9 sowings were made on *Larix laricina* and *Tsuga canadensis.* A few pycnia appeared on the *Larix* on June 25 but there was no further development, although the plants remained in good condition. Pycnia appeared on *Tsuga canadensis* on June 16 and aecia of the *Caeoma* type on June 25. Another sowing on *Tsuga canadensis* on June 19 gave pycnia on June 27 and aecia on July 4, and a

third sowing on June 21 gave pycnia on June 30 with aecia on July 8. Two more sowings were tried on *Larix laricina* without result.

The teliosporic material was collected from a grove of young poplars that were severely attacked by the *Melampsora* the previous season. A visit to the place showed that several young trees of *Tsuga canadensis* grew among the poplars and these were carefully watched for the appearance of aecia. Pycnia and aecia were first collected on June 19. A very rich infection of the trees of *Tsuga* in the immediate vicinity soon followed. The young trees about a foot in height, beneath which were many poplar leaves with the telia of the *Melampsora,* showed an exceedingly rich infection, practically all the leaves and many of the twigs being infected. The poplars were also watched and in due time the uredinia of the *Melampsora* appeared. The distribution was such that it indicated the source of infection to be the *Caeoma* on the *Tsuga.* Similar observations were carried out at Truro, but the place could not be visited often and the observations were not so complete. The observations and cultures leave no doubt in the mind of the writer that the *Melampsora* on *Populus* in the region studied by the writer has aecia on *Tsuga canadensis,* and that the aecia are *Caeoma Abietis-canadensis.* It seems probable that the species discussed is a form of *Melampsora Medusae* with aecia on *Tsuga canadensis.* The weak pycnial infection of *Larix* in one culture seems to support this view but further study is needed. The field collections of aecia were submitted to Dr. Arthur, who confirmed the determination.

A *Caeoma* was often collected in this region on *Larix laricina.* As there seem to be no good characters for separating the aecia of *Melampsora Medusae* and *M. Bigelowii,* both of which have been shown by cultures to occur on *Larix,* it was impossible to determine to which species these collections belonged. The field evidence, though not very strong, indicated that all the collections on *Larix* belonged to *Melampsora Bigelowii* Thüm.

PERIDERMIUM BALSAMEUM Peck

This *Peridermium* was found abundantly on *Abies balsamea* (L.) in all the regions of Nova Scotia visited by the writer.

Field observations made during 1910 seemed to point to *Pucciniastrum arcticum* on *Rubus* as the telial stage (Mycol. 3: 72. 1911). It was also noticed that *Uredinopsis mirabilis* (Peck) Magn. was associated in a very striking way with the same *Peridermium,* but it was not considered probable that they were related. However, as observations made during the early summer of 1911 seemed to point to their connection, a sowing of the *Peridermium* was made on a pot of *Onoclea sensibilis* on July 7. Uredinia were observed abundantly on July 16. At this date the filaments of urediniospores were oozing out. As the plants of *Onoclea* were grown from rhizomes taken into the laboratory in early spring, there was no chance for infection before the sowing. Later study, however, suggested that urediniospores may have been present on the *Onoclea* which grew beneath the *Abies* shoots used in the culture experiment, and that infection may have possibly come from urediniospores clinging to the leaves. It was some time after the appearance of the *Peridermium* that the collection was made for the culture, so that there was sufficient time for the urediniospores to appear on the ferns even if they developed from the aecia on *Abies.* No record was made at the time of collection of the presence of the fern rust, but later it was abundant on the *Onoclea* beneath the fir and may have been present at the time of collection of the aecia.

On July 17 another sowing was made on a number of plants of *Onoclea sensibilis* that had been obtained in the field on the same day. Uredinia appeared on all about July 25. One pot of plants kept as a check remained free from infection, but a few plants of *Onoclea* in the field alongside of those that were used for the culture showed uredinia on July 31. The possibility of the plants being infected before being taken into the greenhouse is not therefore excluded, so the experiment does not establish the connection of the *Peridermium* and the fern rust.

During the season the distribution of *Peridermium balsameum* and *Uredinopsis* on ferns was carefully studied in the field and their association was so marked that the writer concluded it could not be accidental. There was evidence to show that more species than one are included under this *Peridermium.* The first appearance of the aecia was during the last week of June and the

first weeks of July. These aecia appeared to be connected with *Uredinopsis mirabilis* on *Onoclea sensibilis*. A second crop appeared about the first of August and lasted during the month. These seemed to be connected with *Uredinopsis Osmundae* and *U. Phegopteridis*. There was a striking difference between the field appearance of the earlier and later aecia, and the spores of the former averaged about 8 μ smaller than the latter.

The writer is convinced that at least two forms are confused under *Peridermium balsameum* and that these are connected with *Uredinopsis* on ferns. It may be that one is also the aecial stage of *Pucciniastrum arcticum* on *Rubus*. There was considerable field evidence to support this view, but that does not seem probable. Preparations have been made to carry on further experiments next year, and the writer looks forward with confidence to throwing some light on the life history of the fern rusts so little understood at present.

Attempts were made to germinate the urediniospores of *Uredinopsis mirabilis* and with some success. Germ tubes emerged from germ pores, two placed near the beak and two near the base of the spore. The germ tube was that of the usual uredospore but very small. Two germ tubes only emerged from each spore on germination usually, one from the oppositely placed pores either at the apex or base, but sometimes both on the same side of the spore. Attempts were made to infect plants of *Onoclea sensibilis* with uredospores and the experiments were successful but opportunity was not given to follow the experiments carefully. The experiments indicated, however, that the first spore to appear in the fern rust is the uredospore and that it is functionally a uredospore.

PUCCINIASTRUM AGRIMONIAE (Schw.) Tranz

There was a very rich development of both the telial and uredinial stages of this rust on *Agrimonia gryposepala* Wallr. near New Glasgow for several years, but no clue to the aecial stage was noticed. All the conifers of the region grew among the rust except *Tsuga canadensis*. Repeated attempts were made to germinate teliosporic material from this place but without success. Leaves of the host were suspended above young trees of *Tsuga*

canadensis and *Abies balsamea* lest some germinating telia might have escaped detection but there was no result. Uredinia were collected on the young leaves of *Agrimonia* in May, and this would indicate that probably the rust is either carried over the winter by the urediniospores or is perennial in the rootstock or roots, as the young leaves of the conifers were not open at the time of the collection.

SUMMARY OF CULTURES DESCRIBED IN THIS ARTICLE

1. *Life histories supplementing previous work of the writer or other investigators*

Pucciniastrum pustulatum (Pers.) Dietel. Teliospores from *Epilobium angustifolium* L. infected *Abies balsamea* (L.) Mill. Aeciospores from *Abies balsamea* infected *Epilobium angustifolium* L.

Calyptospora columnaris (A. & S.) Kuehn. Teliospores from *Vaccinium pennsylvanicum* Lam. infected *Abies balsamea* (L.) Mill.

Melampsoropsis ledicola (Peck) Arthur. Teliospores from *Ledum groendlandicum* Oeder infected *Picea canadensis* (Mill.) BSP.

Melampsoropsis Cassandrae (Peck & Clinton) Arthur. Teliospores from *Chamaedaphne calyculata* (L.) Moench infected *Picea rubra* (DuRoi) Dietr. and *Picea mariana* (Mill.) BSP.

Melampsoropsis abietina (A. & S.) Arthur. Teliospores from *Ledum groendlandicum* Oeder infected *Picea rubra* (DuRoi) Dietr.

Uromyces Scirpi Burr. Teliospores from *Scirpus campestris* var. *paludosus* (A. Nelson) Fernald infected *Cicuta maculata* L.

Uromyces Peckianus Farl. Teliospores from *Distichlis spicata* (L.) Greene infected *Atriplex hastata* L., *Chenopodium album* L. and *Salicornia europea* L.

Uromyces perigynius Halst. Teliospores from *Carex deflexa* Hornem. infected *Solidago bicolor* L. Teliospores from *Carex scoparia* Schkuhr. infected *Solidago graminifolia* (L.) Salisb., and also *Aster* (*puniceus?*).

Puccinia perplexans Plow. Teliospores from *Alopecurus pratensis* L. infected *Ranunculus acris* L.

Puccinia albiperidia Arth. Teliospores from *Carex intumescens* Rudge, *Carex debilis* var. *Rudgei* Bailey, and *Carex crinita* Lam. infected *Ribes prostratum* L'Hér and teliospores from *Carex crinita* Lam. and *Carex arctata* Boot. infected *Ribes oxyacanthoides* L.

Puccinia Caricis-solidaginis Arth. Teliospores from *Carex scoparia* Schkuhr. infected *Solidago graminifolia* (L.) Salisb. and from *Carex stipata* Muhl. infected *Solidago* (*rugosa?*).

Puccinia Caricis-Asteris Arthur. Teliospores from *Carex trisperma* L. infected *Aster acuminatus* Michx.

2. *Life histories worked out for the first time*

Necium Farlowii Arth. Teliospores from *Tsuga canadensis* (L.) Carr. infected the same species.

Melampsoropsis Pyrolae (DC.) Arth. Teliospores from *Pyrola Americana* Sweet and *Pyrola elliptica* Nutt. infected cones of *Picea mariana* (Mill.) BSP. and *Picea canadensis* (Mill.) BSP. (*Peridermium conorum-Piceae* (Rees) Arthur).

Pucciniastrum minimum (Schw.) Arthur. Teliospores from *Rhodora canadense* (L.) BSP. infected leaves and cones of *Tsuga canadensis* (L.) Carr. (*Peridermium Peckii* Thüm.).

Uromyces Spartinae Farl. Teliospores from *Spartina Michauxiana* Hitch. infected *Arenaria lateriflora* L. but failed to infect *Spergularia canadensis* (Pers.) Don. Teliospores from *Spartina patens* (Ait.) Muhl. and *Spartina glabra* var. *alterniflora* (Loisel) Merr. infected *Spergularia canadensis* but failed to infect *Arenaria lateriflora* L.

Melampsora arctica Rostr. Teliospores from *Salix discolor* Muhl. infected *Abies balsamea* (L.) Mill.

Melampsora (*Medusae* Thüm.?) Teliospores from *Populus grandidentata* Michx. infected *Tsuga canadensis* (L.) Carr. (*Caeoma Abietis-canadensis* Farl.).

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